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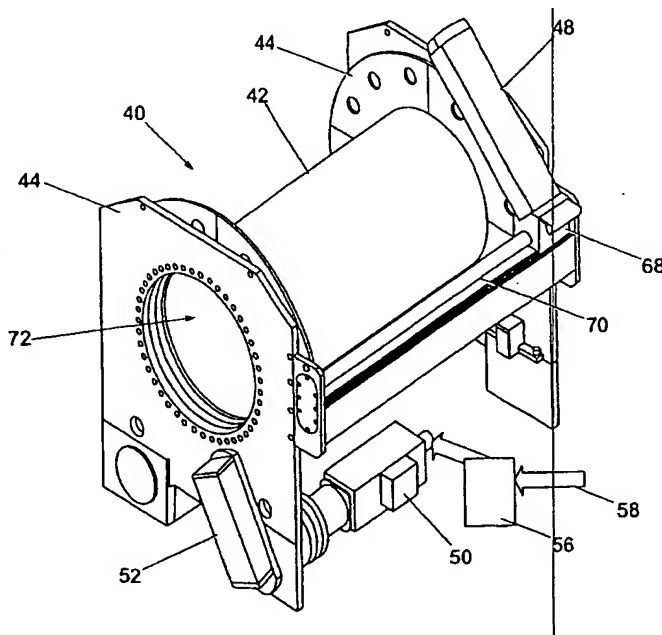
(57) Abstract: A winch for use in a heave compensation system has a winch drum (42) driven by an AC asynchronous motor (50) via a gearbox (52). The motor (50) is controlled by a variable speed control (58) as a function of heave speed. The motor (50) and its drive train, and the winch (42), are chosen to have low inertia. The winch pays out and reels in to compensate for heave substantially instantaneously, without the need for prediction of wave patterns.

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1   MARINE HEAVE COMPENSATING DEVICE AND WINCH DRIVE

2

3   This invention relates to reeling and winch systems, and

4   in particular to systems for use in maritime

5   applications.

6

7   Typically, a maritime reeling system is mounted on a

8   vessel to control a cable from which an article is

9   suspended in the water from the vessel, either over the

10   side or through a moonpool or the like. The vessel may

11   be a ship, semi-submersible rig, oil platform or other

12   floating vessel. The suspended article may be, for

13   example, drilling equipment, test equipment, or an

14   inspection chamber. In many applications of this nature,

15   it is necessary for the suspended article to be held at a

16   substantially fixed location, for instance to avoid

17   damage to drilling equipment. In other situations it is

18   important to maintain constant tension but not

19   necessarily support a load, for example in handling

20   tethers or umbilicals for remotely operated vehicles

1   (ROVs) and diving bells or the like. The former type of

2   situation is commonly called "winching" and the latter

3   "reeling", but the term "reeling" is used herein to

4   encompass both.

5

6   In all of these situations, wave motion will cause the

7   vessel to move up and down ("heave"), so that

8   arrangements have been used to provide heave compensation

9   in reeling systems.

10

11 Many prior art heave compensation systems use pneumatic

12 or hydraulic control systems to drive a winch, there

13 being an arrangement for recording the recent history of

14 heave movement to provide a prediction of future

15 movement, thereby allowing the winch to be controlled to

16 pay out or reel in cable in an attempt to compensate

17 future heave. However, such systems have limited

18 usefulness owing to the non-uniformity of real life wave

19 patterns. Also, the compressibility of the working fluid

20 in pneumatic and hydraulic systems inevitably introduces

21 time lags.

22

23 It is also known to use electrically powered winches

24 controlled by electric systems. Hitherto, such winches

25 have mostly been powered by DC motors because of the

26 speed/torque characteristics of such motors, particularly

27 the provision of high torque at low speed, but the use of

28 AC motors is also known.

29

30 The commonest system is to use a single DC motor which is

31 controlled to follow a desired torque. This leads to a

32 phase lag between torque and speed, and hence between the

33 input command signal and speed, which phase lag can only

1   be accommodated by the use of predictive controls.

2

3   It is also known to use two DC motors operating via a

4   common mechanical drive system. One of the motors is a

5   low speed, high torque motor and the other a low torque,

6   .high speed motor. The first motor is used for the main

7   raising and lowering functions, and the second motor to

8   provide relatively rapid heave compensation motion.

9   However, this approach substantially increases weight,

10 bulk and complexity.

11

12 In prior art heave compensation systems using AC motors,

13 the motor has been controlled in terms of torque and, as

14 with systems using a single DC motor, this leads to a

15 phase lag between the input control signal and the speed

16 of the motor.

17

18 This may be further explained with reference to Fig 1,

19 which illustrates the response of a prior art system

20 using a winch driven by a high torque, low speed electric

21 motor, either DC or AC. Since such a motor has low speed

22 and low acceleration, the control input 28 is a torque

23 demand signal. The motor torque 30 follows the control

24 input closely but, because of the inherent

25 characteristics of the motor, is rough (jerky). The

26 motor speed 32 then follows as a function of the motor

27 torque 30, with a phase lag, and also with a rough form.

28 There is thus a phase lag in the heave compensation

29 itself, and the jerkiness of the motion is detrimental to

30 the fatigue life of the system.

31

32 Moreover, in prior art systems whether using hydraulic,

33 DC or AC motors, the motor has been chosen to have a

1   maximum torque output which is equal to the maximum
2   torque required by the worst anticipated sea state, that
3   is a motor which is capable of providing such torque on a
4   continuous basis. This leads to the use of a motor
5   having a high inertia, which in turn increases the
6   response time of the winch.
7
8   US-A-4,547,857 is one example of a predictive heave
9   compensation system using either a hydraulic or an
10   electric winch motor.
11
12   US-A-4,434,972 discloses a hydraulic hoisting arrangement
13   in which a winch drum is driven through a gear train and
14   freewheel arrangement by two hydraulic motors: a high-
15   torque, low-speed motor for hoisting, and a low-torque,
16   high-speed motor for compensating.
17
18   These and other prior art proposals suffer from system
19   time lags which introduce a phase shift between the sea
20   surface waveform and the motion of the hoisting drum.
21
22   The present invention provides a dynamic winch for use in
23   a heave compensation system, comprising a winch drum and
24   an electric motor connected to rotate the winch drum; and
25   in which the electric motor is an AC motor controlled by
26   a variable speed drive.
27
28   From another aspect, the invention provides a maritime
29   reeling system comprising a winch as defined in the
30   preceding paragraph mounted on a marine structure, and a
31   sensor arranged to sense a parameter associated with
32   heave in the vicinity of said structure, said sensor

1   being connected to supply an input signal to said

2   variable speed drive.

3

4   An embodiment of the invention will now be described, by

5   way of example only, with reference to the drawings, in

6   which:

7   Fig 1 illustrates the system response in a typical

8   prior art heave compensation system, as discussed above;

9   Fig 2 is a schematic side view of a vessel from

10 which an item is suspended by a winch system;

11   Fig 3 schematically shows idealised wave motion of

12 the surface of the sea;

13   Fig 4 shows typical actual sea conditions;

14   Fig 5 illustrates one system embodying the present

15 invention;

16   Fig 6 illustrates the system response of the system

17 of Fig 5; and

18   Fig 7 is a schematic diagram of the drive

19 arrangement for the system of Fig 5.

20

21 Fig 2 shows schematically a vessel 10 on the sea surface

22 12 and supporting a load 14 from a cable 16 by means of a

23 crane, derrick or overboarding sheave arrangement 18,

24 controlled by a reeling system (hereinafter termed a

25 "reeler") 20. The reeler is able to reel in or pay out

26 the cable 16 in order to raise or lower the load relative

27 to the vessel 10.

28

29 In particular, the reeler 20 is intended for use with an

30 umbilical, for deploying, retrieving and storing the

31 umbilical in a manner which protects the umbilical

32 against damage. Umbilicals may be complex and expensive

33 items, incorporating services such as electrical,

1   hydraulic or pneumatic power supplies, signal cables,

2   fibre optics and the like, and therefore vulnerable to

3   expensive damage if not handled appropriately.

4

5   The sea surface 12 will normally have waves moving across

6   it, causing the vessel 10 to heave as the waves pass

7   beneath it. Fig 3 shows an idealised profile of the

8   surface 12, which is sinusoidal, as assumed for example

9   in standard works such as Lloyds directory of Shipping.

10   ₍This Directory provides reference data concerning the

11   amplitude and frequency of waves expected in different

12   sea states and in different sea areas. In reality, the

13   motion of the sea surface will rarely be as uniform as

14   suggested by Fig 3 and may exhibit variations such as

15   those shown in Fig 4, in which the amplitude and

16   frequency of the waves each varies with time and

17   position. Thus, the wave motion may be relatively large

18   in amplitude and low in frequency, as indicated generally

19   at 22; or lower in amplitude but still lower in frequency

20   as indicated at 24; or high in amplitude and high in

21   frequency as indicated at 26. Many other sea states may

22   be encountered. In practice the variations encountered

23   will depend on the sea area being considered, weather

24   conditions, tidal conditions, and the like, resulting in

25   the vessel moving in a combination of heave, pitch, yaw

26   and roll.

27

28   The present invention seeks to track the heave

29   substantially without phase shift, thus avoiding the need

30   for predictive techniques.

31

32   Fig 5 illustrates a maritime reeling system in accordance

33   with the present invention. The system 40 has a drum 42

1   rotatably mounted in side cheeks 44 by appropriate

2   bearings. The drum 42 will carry a cable (not shown) for

3   paying out or reeling in by rotation of the drum 42 in an

4   appropriate sense. Cable guides 48 are provided, as will

5   be described in more detail below, to assist in providing

6   accurate spooling of the cable onto the drum 42, to

7   minimise damage to the cable. Power to turn the drum 42

8   is provided by a motor 50 coupled with the drum by a

9   drive train indicated generally at 52 at one end of the

10   drum 42. The drive train 52 may incorporate gearboxes

11   and the like.

12

13   The motor 50 is an AC motor, of a type well known in

14   itself. The requirements for the motor in the present

15   system are discussed in more detail below. The motor 50

16   receives power from a control circuit 56 which is

17   preferably remote from the motor 50. The control circuit

18   56 is arranged, as will be discussed in more detail

19   below, to supply power to the motor 50 in such a manner

20   that the motor speed follows an input signal 58. The

21   input signal 58 is preferably representative of the speed

22   of the load 14 relative to a fixed frame of reference

23   (the sea bed), but could alternatively be a function of

24   the acceleration of the load, the absolute position of

25   the load, or the tension in the cable 16.

26

27   One suitable arrangement, indicated in Fig. 1, is a

28   sensor 60 (for example, an ultrasonic sensor) located on

29   the vessel 12 to measure the instantaneous distance

30   between the vessel and the sea bed, from which the

31   instantaneous speed may be derived.

32

1   In the event of the sea surface being entirely flat,
2   which is most uncommon, no heave compensation will be
3   required. The input 58 will indicate zero load speed,
4   and consequently the controller 56 will provide zero
5   input to the motor 50. Once the sea surface 12 begins to
6   move, the input 58 will indicate speed of the load 14
7   relative to the sea bed, and the control circuit 56 will
8   immediately respond by instructing the motor 50 to turn
9   in the appropriate direction to cause the system 40 to
10   pay out or reel in cable in order to negate the heave,
11   the motor being controlled to attain a target speed
12   equivalent to the instantaneous speed of the load.
13
14   The nature of the motor 50 and the fact that it is speed
15   driven allows the control circuit 56 to respond directly
16   to any change in load speed or position being sensed.
17   That is to say, the drum 42 can start turning almost
18   instantly as soon as any change in load speed or position
19   is sensed. Because of the speed of response, and by
20   arranging to provide adequate power output from the motor
21   50 and low inertia within the system, the cable can be
22   paid out or reeled in sufficiently rapidly to track the
23   heave, so that the load 14 can be retained at an
24   accurate, fixed position.
25
26   This speed of response contrasts markedly with the
27   response characteristics of a predictive system using
28   hydraulics, pneumatics or a DC electric motor, and allows
29   the system to track the instantaneous position without
30   any requirement for prediction, and therefore providing
31   the ability to respond immediately to any changes in wave
32   amplitude, frequency or shape. The problems associated
33   with a predictive system are thereby substantially

1 avoided. The heave compensation provided by a system
2 according to the present invention can remain in phase
3 with the sea motion being experienced, at all times, by
4 virtue of the substantially instantaneous response
5 achieved by electronic control in conjunction with an AC
6 motor and low inertia components.
7
8 Fig 6 shows the system response of the system of Fig 5.
9 The input signal 34 is a speed signal, and the motor is
10 driven to have its speed 36 follow the input signal 34.
11 The motor speed 36 is smooth and substantially in phase
12 with the input signal 34. The winch will accelerate and
13 decelerate smoothly and always be in phase with the
14 motion input. The motion torque curves will always be
15 out of phase with the speed curve.
16
17 An AC motor will have a minimum rotation speed below
18 which operation is not possible or is unpredictable, so
19 that it is preferable for the control circuit 56 not to
20 instruct motor movement when the load position is
21 changing at a rate lower than a predetermined threshold
22 rate. However, when changing at a very low rate, tension
23 on the cable will be changing only very slowly and thus
24 not dangerously for the integrity of the cable. Applying
25 a threshold in this manner will have the effect of
26 damping the peaks of the wave motion by not responding to
27 the wave shape at or close to the peak, but it is
28 envisaged that by appropriate design or choice of motor
29 this damping can be reduced to an extent at which cable
30 damage is avoided. The use of the threshold has the
31 advantage of preventing the system hunting in the event
32 of small changes being experienced.
33

1 The drive train to the drum 42 is shown in more detail,

2 schematically, in Fig 7. As has been described, the

3 motor 50 is controlled by the control circuit 56, which

4 is an electrical variable speed drive unit. Suitable

5 variable speed drive units include the "Midimaster"

6 vector drive by Siemens and the "ALSPA MV3000" by Alstom

7

8 The motor 50 drives a gear box 62 mounted on one side

9 cheek 44, which in turn drives the outer ring 64B of a

10 ball race 64, by means of a pinion 66. The outer ring

11 64B is secured to the drum 42 and co-operates with an

12 inner ring 64A secured to the side cheek 44, so that

13 operation of the motor 50, through the gear box 62 and

14 pinion 66, will cause the drum 42 to rotate within the

15 stationary side cheeks 44.

16

17 In the interests of the speed of response, the design of

18 the drive train should be chosen to minimise delays in

19 the response of the system, particularly from inertia and

20 friction.

21

22 The control circuit 56 can be substantially wholly

23 electrical or electronic, receiving electrical signals

24 from sensors such as 60, so as to minimise delays in the

25 system.

26

27 The motor 50 should be selected for low inertial

28 properties. Examples are commercially available, such as

29 the flux vector drive motors manufactured by Siemendori

30 or by Siemens. Similarly, the design of gear box 62

31 should be chosen for low inertial properties and could be

32 a Cyclo gear box manufactured by Sumitomo, or a compound

33 gearbox type. The components of the ball race 64 can

1 also be designed for minimally increasing the moment of

2 inertia of the drum 42, by appropriate choice of

3 materials, sizes and the like. Reduction of moments of

4 inertia within the system reduces the overall torque

5 requirement of the motor 50, thus allowing a low inertia

6 motor to be used, with further improvement in the

7 response time of the system. The drive train can also be

8 designed to reduce backlash, particularly in the gear box

9 62.

10

11 The choice of the motor 50 will be governed by the

12 following considerations. In an AC motor the speed and

13 torque are linked. Maximum torque can be developed at

14 any speed up to a certain maximum (the synchronous speed)

15 determined by the physical characteristics of the

16 machine. Above the synchronous speed, the torque

17 available will decrease. If the synchronous speed is

18 high, the motor must be mechanically capable of carrying

19 the maximum torque at high speed, and this will have an

20 influence on the inertia of the motor and thus on the

21 speed of response. With a low synchronous speed

22 (typically about 1500 rev/min) the inertia of the motor

23 will be low and its response time fast.

24

25 If the motor is chosen to provide a maximum power

26 determined by the worst anticipated heave (worst sea

27 state), the motor will be mechanically large with a high

28 inertia and poor response time. However, since the sea

29 waves are approximately sinusoidal, the maximum power is

30 required only for a fraction of the wave period. In the

31 remainder of the period a lower power is required. We

32 have established that in the sea conditions of interest

33 the required power is lower than 60% of the worst maximum

1 power (worst sea state) for 80% of the wave period.

2 Therefore, in preferred embodiments of the present

3 invention the winch motor is chosen to have an

4 intermittent power rating which can handle the worst sea

5 state acceleration and power requirement for 20% of the

6 cycle (typically 60 s in a cycle of 300 s), and to be

7 capable of handling 60% of the worst sea state power

8 requirement for the remainder of the time.

9

10 The worst sea state imposes a requirement for very high

11 acceleration during part of the wave cycle. In the

12 preferred forms of the invention, a motor of low

13 synchronous speed is used, Consequently, during parts of

14 the wave cycle the motor will operate above its

15 synchronous speed and torque will tend to fall. When

16 operating above synchronous speed, the motor can produce

17 the required torque by increasing its power, which is a

18 function of speed and torque, above its continuous rated

19 power.

20

21 Therefore, the preferred motor is chosen to be capable of

22 producing 150% of its maximum rated continuous power for

23 up to 60 s, and of producing 90% of its maximum rated

24 continuous power for 240 s thereafter. That is, the

25 preferred motor has a maximum continuous rated power

26 equal to the substantial part of the worst sea state

27 power and acceleration requirement. Other combinations of

28 intermittent and continuous ratings will be possible

29 within the general concept of using a motor with a

30 continuous rating less than the worst sea state maximum

31 power and acceleration requirement. In this way a motor

32 of minimum inertia is provided.

33

1   Any heave compensation being effected in the manner

2   described above may be used to maintain the load 14 in a

3   fixed position, or may be superposed on drum rotation

4   required for a given deployment or retrieval of the load

5   14, so that deployment or retrieval can be a steady

6   operation even with heave of the vessel 10.

7

8   The reeler 20 is capable of suspending a load on the

9   surface of the sea without producing any unnecessary

10 strain on the umbilical used for deploying the suspended

11 load, because the swell on the sea is substantially

12 instantaneously compensated by the arrangements

13 described. Synchronising the umbilical length to the sea

14 motion in this way is possible even if the vessel 10 is

15 being driven in the horizontal plane.

16

17 Referring again to Fig 5, the winch is provided with a

18 level wind mechanism in which cable being paid out or

19 reeled in passes through guides 48 in the form of

20 elongate parallel rollers and other devices mounted at

21 one end on a shuttle 68. The shuttle 68 is movable along

22 a threaded shaft 70 parallel to the axis of the drum 42,

23 the shaft 70 being rotated by an electric motor (not

24 shown) to drive the shuttle 68 along the shaft 70. The

25 motor is preferably controlled by the control circuit 56

26 (or another circuit communicating with the circuit 56)

27 such that movement of the guides 48 along the drum 42 is

28 synchronised with rotation of the drum 42 to achieve an

29 accurate helical laying of the cable 16 on the drum 42.

30 The same inertia requirement and acceleration apply to

31 the level wind assembly.

32

1   The control arrangements for rotating the shaft 70

2   operate to match the speed of rotation of the drum 42

3   with the speed of movement of the guides 48 along the

4   shaft 70, at a fixed ratio dependent on the diameter of

5   the umbilical being reeled. If a different diameter

6   umbilical is to be used, then a new ratio and speed can

7   be selected, for which reason it is convenient for the

8   shaft 70 to be controlled by an electronic control

9   system, electronic gearbox, or the like, to allow ready

10   adjustment of the ration being used. In this way, the

11   co-ordination of the two motor speeds can be highly

12   sophisticated, such as to change at different points

13   along the length of the umbilical in the event that the

14   umbilical diameter is not constant along its length. The

15   position or speed of the drum 42 can be provided for

16   control of the shaft 70 by encoders at an appropriate

17   location within the drive train to the drum 42.

18

19   Accurate helical laying of the umbilical on the drum 42

20   is important in preventing damage and wear of the

21   umbilical, particularly by chafing or abrasion.

22   Consequently, the guides 48 must be positioned with a

23   response time fast enough to match the response times

24   with which the drum 42 can be rotated, and this is

25   facilitated by the use of electronic control of the shaft

26   70 and by the choice of low inertia components.

27

28   It is apparent from Fig 5 that the arrangements for

29   driving the drum 42 are located outside the drum, so that

30   the centre 72 of the drum can be open and substantially

31   unobstructed. This provides a number of advantages.

32   First, the open drum centre provides a location for

33   couplings to the end of the cable 16, such as for power

1   transfer, fibre optic connections, or the like.

2   Secondly, the open nature of the centre 72 provides for

3   air or water cooling of the drum 42 from within. This

4   can be important in practice, particularly when the cable

5   16 is conducting electrical power to the load 14. Power

6   being conducted along the cable 16 will tend to give rise

7   to inductive heating effects due to the coiled nature of

8   the cable 16 around the drum 42, which can be offset by

9   cooling via the centre 72.

10

11   It is envisaged that when the cable is being paid out

12   resistive braking external to the motor 50 or elsewhere

13   in the drive train can be used to control drum motion,

14   and also to generate electrical power which can be

15   provided to the vessel 10 to reduce the mean power

16   requirement of the winch arrangement or for other

17   purposes. In addition, the magnetic nature of the motor

18   allows the drum position to be located almost

19   instantaneously when stopping, without any bounce.

20

21   The load illustrated in Fig 1 is an item such as a piece

22   of equipment hanging from the cable 16. Alternatively,

23   the load could be the weight of a cable being laid on the

24   seabed, with the heave compensation arrangement used for

25   shock absorbing. As another alternative, the load could

26   be the tension in a mooring cable, towing cable or the

27   like. While the vessel 10 is illustrated as a ship, it

28   will be apparent that similar problems are experienced

29   with semi-submersible oil rigs and other floating

30   structures, and in transferring loads between fixed

31   structures (such as seabed-located oil rigs) and floating

32   structures (such as supply vessels). In one application

33   envisaged for the invention, heave compensation would be

1   provided for a tanker loading from a subsea oil well

2   installation.

3

4   The apparatus described above may be modified without

5   departing from the scope of the present invention as

6   defined in the appended claims. More than one sensor may

7   be used for detecting the motion to be compensated. For

8   instance, sensors could be provided on the load, on the

9   vessel, on the sea surface, or on the seabed.

10

11

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20

1   CLAIMS

2

3   1.   A dynamic winch for use in a heave compensation
4   system, comprising a winch drum and an electric
5   motor connected to rotate the winch drum; and in
6   which the electric motor is an AC motor
7   controlled by a variable speed drive.

8

9   2.   A winch according to claim 1, in which the motor
10   has a sufficiently high speed and acceleration
11   and the winch has a sufficiently low inertia to
12   follow a speed signal input substantially
13   instantaneously.

14

15   3.   A winch according to claim 1 or claim 2, in
16   which the motor is a flux vector drive motor.

17

18   4.   A winch according to any preceding claim, in
19   which the motor is selected in relation to the
20   maximum anticipated sea state acceleration and
21   power requirement to have a continuous power
22   rating less than the maximum sea state required
23   power and to be capable of producing the maximum
24   sea state required power for a fraction of the
25   anticipated wave sinusoidal cycle.

26

27   5.   A winch according to claim 4, in which the motor
28   is selected to be capable of producing the
29   maximum sea state required power for 20% of the
30   wave cycle and 60% of that power for the

1   remainder of the wave cycle when the motor is

2   running past synchronous speed.

3

4   6.   A winch according to claim 5, in which the motor

5   can produce 150% of its continuous rated power

6   for 20 s in a 300 s period.

7

8   7.   A winch according to any preceding claim, in

9   which the winch drum is mounted for rotation

10   between stationary cheeks, and the motor drives

11   the drum via a gear train secured to the

12   exterior of one of said cheeks.

13

14   8.   A winch according to claim 7, in which the winch

15   drum has an open centre.

16

17   9.   A winch according to any preceding claim,

18   including a level wind mechanism driven by a

19   second electric motor synchronised with the

20   motor which drives the winch drum.

21

22   10.   A maritime reeling system comprising a winch in

23   accordance with any preceding claim mounted on a

24   marine structure, and a sensor arranged to sense

25   a parameter associated with heave in the

26   vicinity of said structure, said sensor being

27   connected to supply an input signal to said

28   variable speed drive.

29

1   11.   A system according to claim 10, in which said
2   parameter is the vertical speed of the water
3   surface or of an object floating on it.
4
5   12.   A system according to claim 10, in which said
6   object is the marine structure on which the
7   winch is mounted.
8
9   13.   A system according to claim 10, in which said
10   object is the winch load.
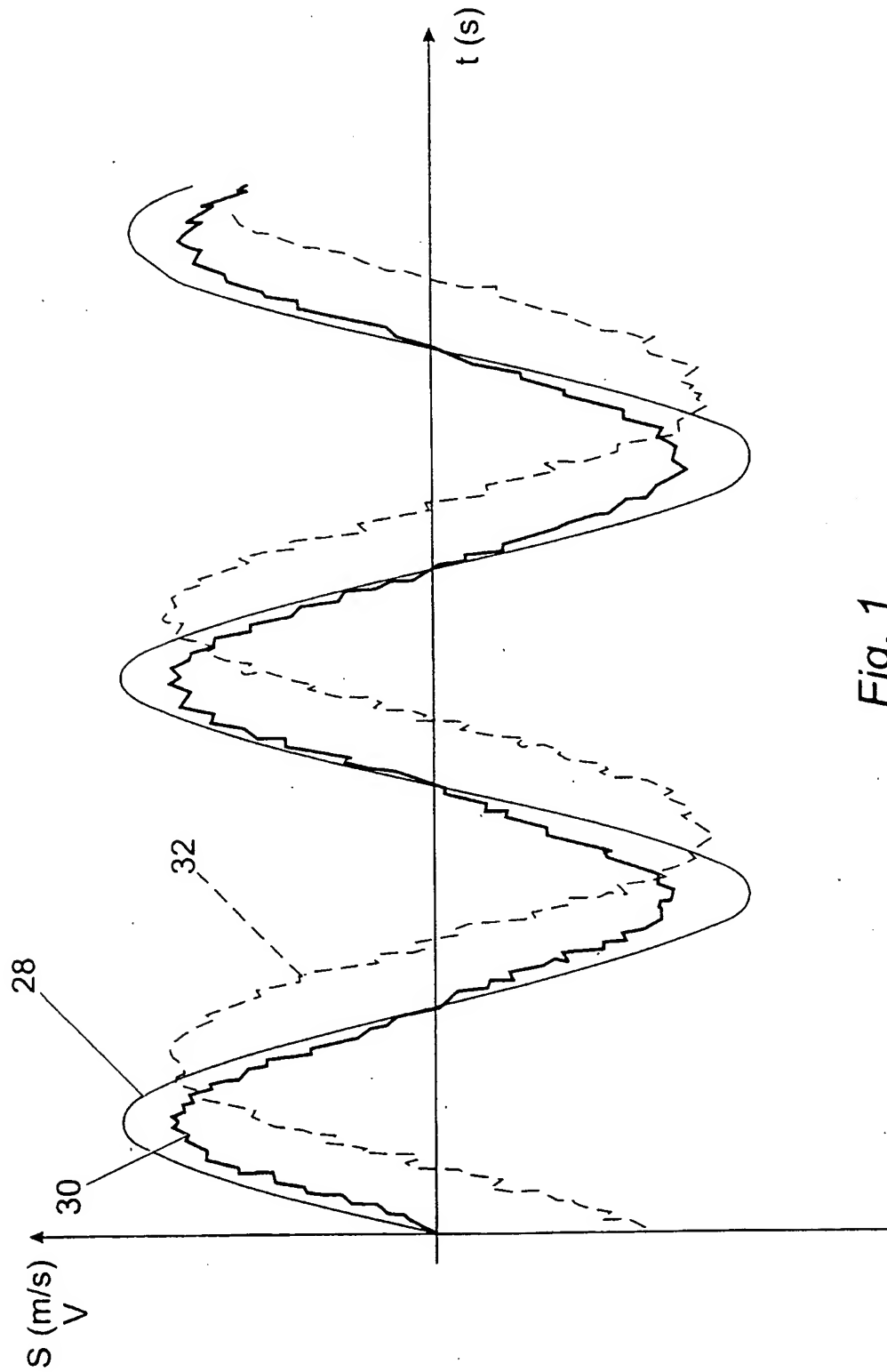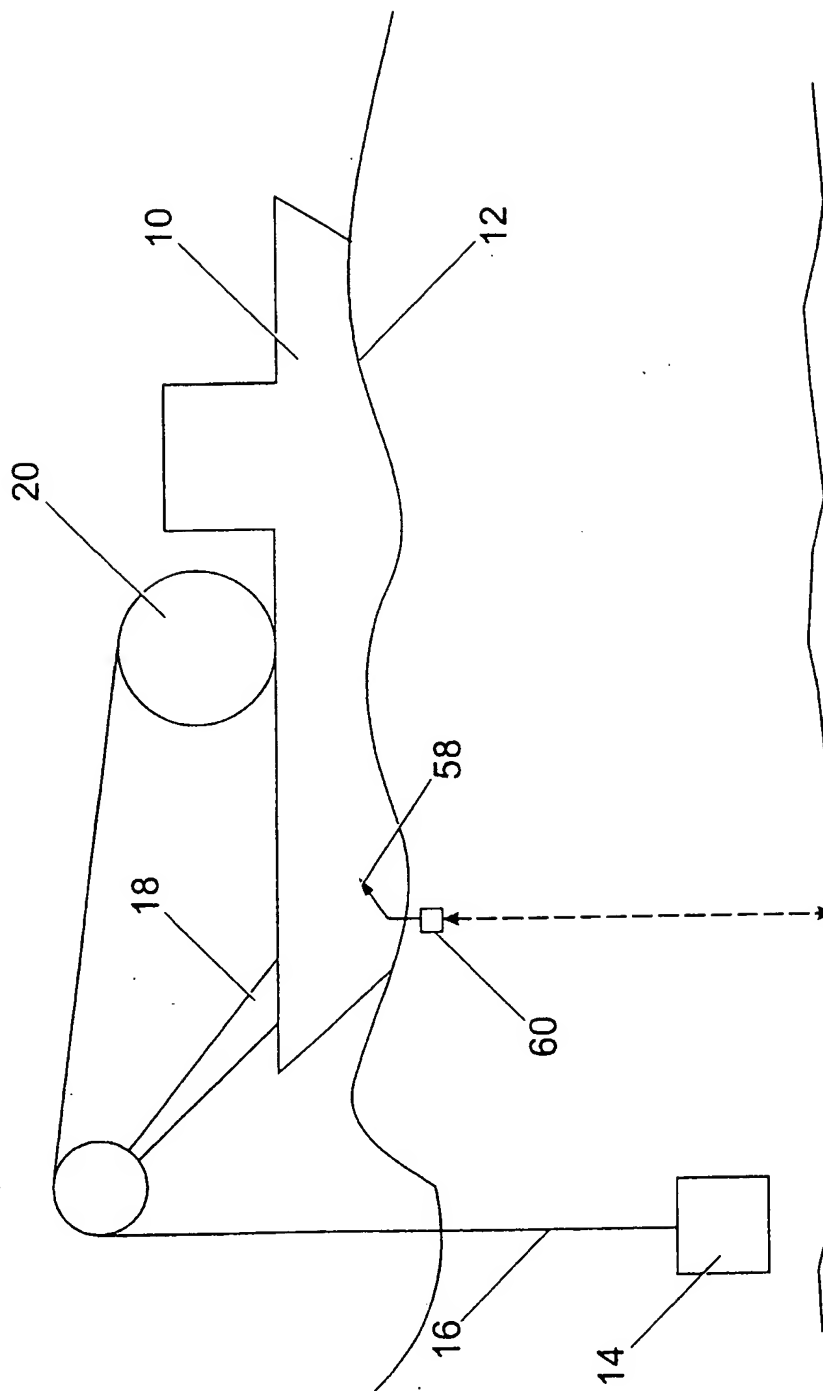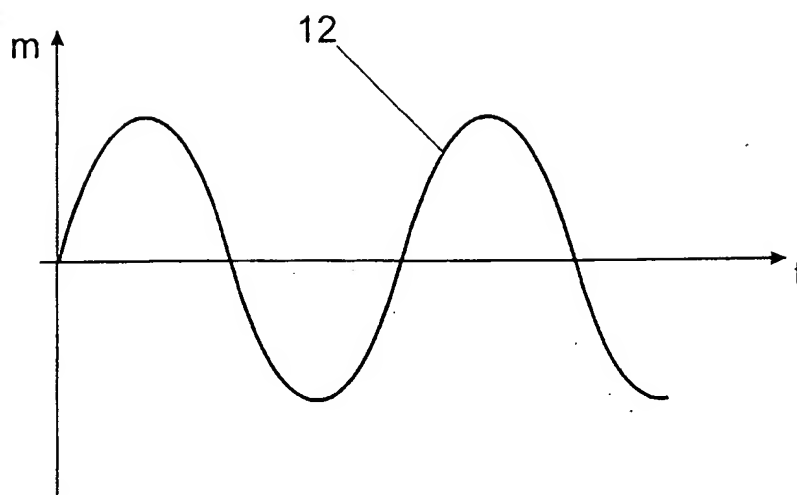11
12
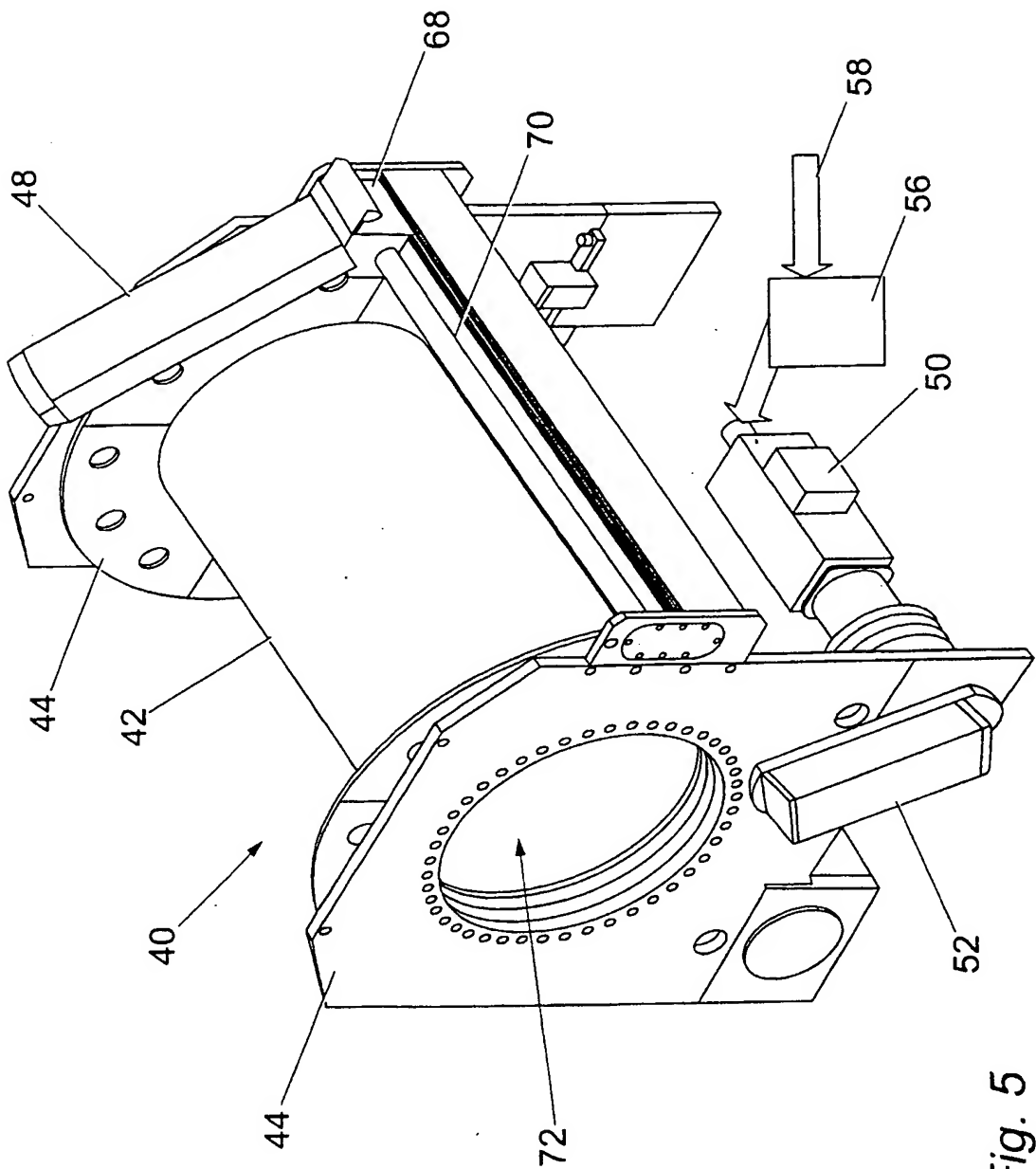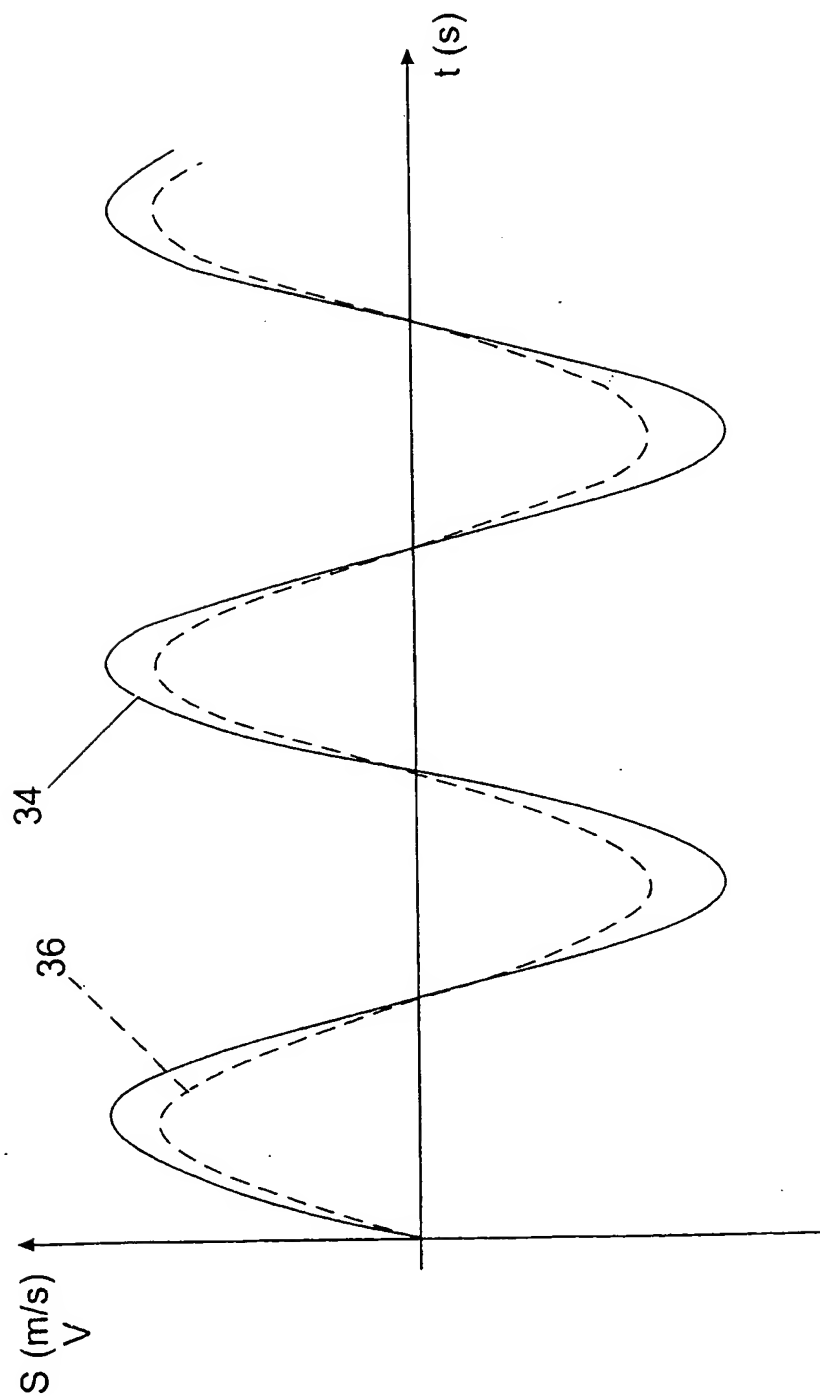
Fig. 1

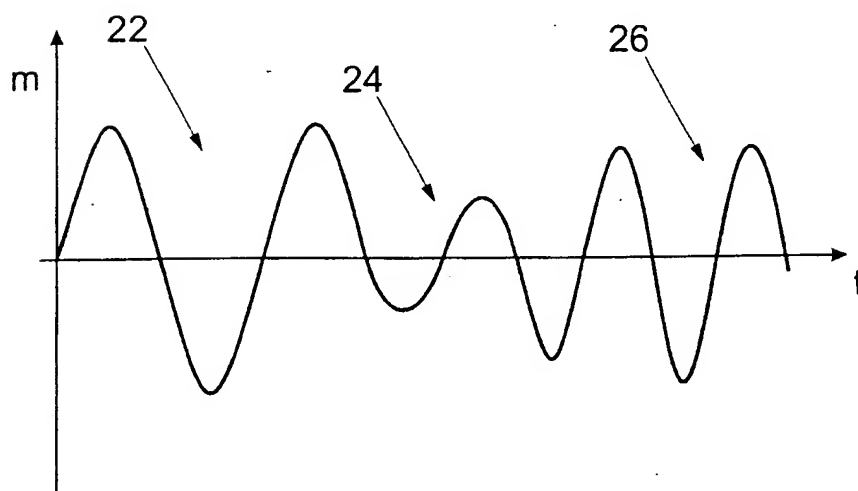Fig. 2

Fig. 3

Fig. 4

Fig. 5

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Fig. 6
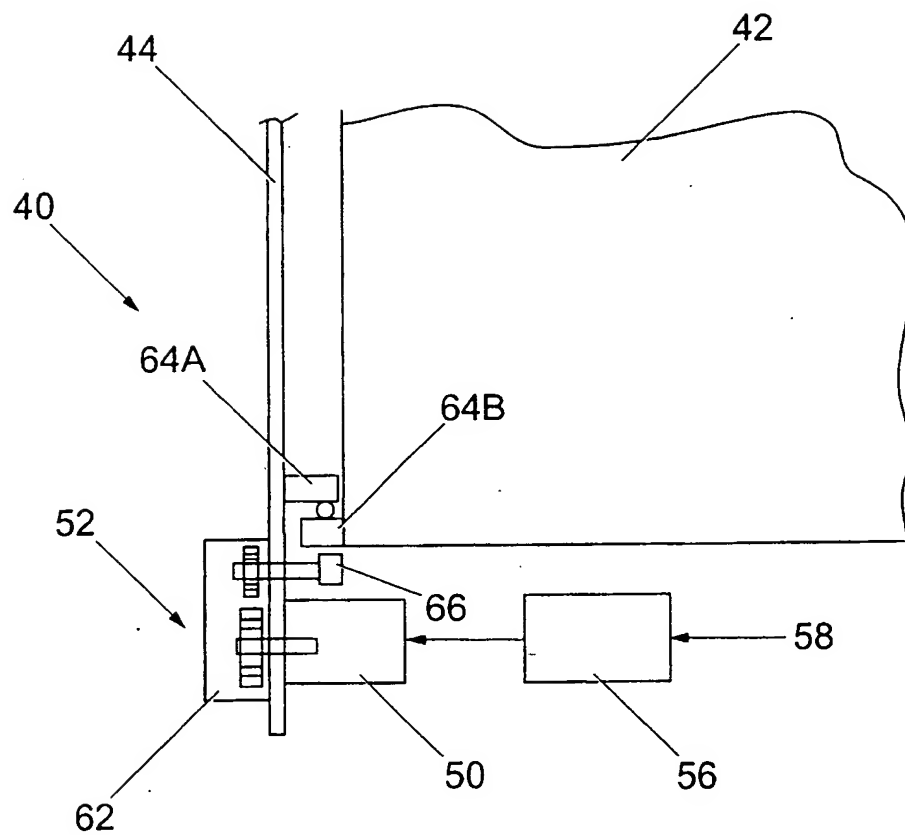
Fig. 7

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   B66D1/52   B66D1/50   B66D1/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   B66D   H02P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category°	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 676 365 A (HATLAPA UETERSENER MASCHF) 11 October 1995 (1995-10-11)	1-6
Y	the whole document	7-13
Y	US 4 736 929 A (MCMORRIS MICHAEL L) 12 April 1988 (1988-04-12) abstract figures 2,3	7,8
Y	DE 38 32 192 A (BROEHL GMBH & CO OHG MASCHF) 27 July 1989 (1989-07-27) abstract figure 1	9
	-/--	

[X] Further documents are listed in the continuation of box C.   [X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 March 2001	22/03/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Sheppard, B

page 1 of 2

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	US 5 894 895 A (WELSH WALTER THOMAS) 20 April 1999 (1999-04-20) abstract column 3, line 9 - line 29 column 7, line 20 -column 8, line 53 figure 1	10-13
A	EP 0 335 269 A (YASKAWA DENKI SEISAKUSHO KK) 4 October 1989 (1989-10-04) abstract page 7, line 30 - line 35	3
A	DETERING R L: "FLUX VECTOR CONTROL FOR AC MOTORS" MACHINE DESIGN,US,PENTON,INC. CLEVELAND, vol. 61, no. 18, 7 September 1989 (1989-09-07), page 176,178 XP000068250 ISSN: 0024-9114 the whole document	3

INTERNATIONAL SEARCH REPORT

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